

**APPARATUS AND METHOD FOR PREDICTING PHYSICAL
TOPOLOGIES WITHIN OPTICAL NETWORKS**

BACKGROUND OF THE INVENTION

5

Field of Invention

The present invention relates to networks and, more specifically, to predicting physical topologies within networks.

10

Description of the Related Prior Art

A network commonly includes a plurality of domains or spans, each span comprising a plurality of nodes coupled together with physical connections. A span can be configured in numerous different manners including a ring such as a Bidirectional Line Switched Ring (BLSR) or a mesh. Each span is generally controlled by an Operations Controller (OPC), also known as a Managed Object Agent (MOA), while a Network Manager further controls the overall operation of the network by controlling the various OPCs.

The physical connections between nodes of each span and the physical connections between the spans make up the overall physical topology of the network. It is important for the network administrator, whether consisting of a person or an automated processor within the Network Manager, to have knowledge of the physical topology of the network to accomplish a number of operations including the provisioning of bandwidth and to aid in the correlating of alarms. Further, it is important to have knowledge of the physical topology of the network in order to aid in the planning of expansions to the network.

Unfortunately, after a network of nodes is connected, only logical connection information is visible at the nodes. This logical connection information is often, but not necessarily, represented as Connection Termination Points (CTPs). The physical connections may be unknown to the nodes, OPCs and Network Manager of the network.

A well-known technique in which the physical topology of a network can be generated is with the manual collecting 10 of physical connection information. For instance, at the time of constructing the network, each physical connection that is established between nodes of the network could be recorded into a central physical topology database. With the systematic entry of information with respect to the 15 physical connections, an overall picture of physical topology can be generated.

There are a number of problems with this manual entering of physical topology information. For instance, 20 one problem with this manual technique is the potential of a technician making an error or an omission when entering the physical connection information into the central physical topology database. Further, there is the potential that the physical topology database might mistakenly not be updated 25 to coincide with future changes to the network, such as expansions. Still further, this technique cannot be used if you require the physical topology of a pre-existing network.

After the establishment of the network, to check the 30 recorded physical connections and/or to gain physical connection information in the case that not all physical connections were recorded, a technician would need to manually follow each physical cable to determine which ports

within which nodes are physically connected together. This process of manually following physical cables is not practical for large networks due to the excessive amount of labour required and the fact that the results would likely 5 be prone to errors in a similar fashion to the entering of physical connection information at the time of establishing the network.

Therefore, there is a need for a technique to capture 10 and/or check the physical connections within a network in a manner that does not require manual collection of physical connection information.

SUMMARY OF THE INVENTION

15 The present invention is directed to an apparatus and method for predicting a physical topology for a network using information related to the logical connections within the network. The technique of one embodiment of the present 20 invention includes receiving logical connection information associated with ports within nodes of the network, preparing the logical connection information such that it is easier to determine which ports are logically similar, and predicting physical connections between ports by finding, for each port 25 within the network, at least one other port that is logically similar. In some embodiments of the present invention, other techniques for discovering the physical connections within a network are utilized such as auto-discovery.

30 In a first broad aspect, the present invention is a processing apparatus arranged to be coupled to a network of nodes linked together by physical connections. The

processing apparatus includes a receiver and a processor coupled to the receiver. The receiver operates to receive at least one logical connection parameter associated with each of at least one port within a plurality of the nodes.

- 5 The processor operates to process the received logical connection parameters in order to predict at least one physical connection between two of the ports within the plurality of nodes based upon the results of the processing.

10 According to a second broad aspect, the present invention is a method of predicting at least one physical connection within a network of nodes linked together by physical connections. The method includes receiving at least one logical connection parameter associated with each of at least one port within a plurality of the nodes; processing the received logical connection parameters; and predicting at least one physical connection between two of the ports within the plurality of nodes based upon the results of the processing.

15
20 The present invention according to a third broad aspect is a network including a plurality of nodes linked together by physical connections and at least one processing apparatus arranged to be coupled to the nodes. The processing apparatus operates to receive at least one logical connection parameter associated with each of at least one port within a plurality of the nodes; and process the received logical connection parameters in order to predict at least one physical connection between two of the ports within the plurality of nodes based upon the results of the processing.

Other aspects and advantageous features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with
5 the accompanying figures.

BRIEF DESCRIPTION OF THE FIGURES

Preferred embodiments of the present invention will now
10 be described in detail with reference to the following
figures:

Figure 1 is a block diagram illustrating an optical network in which the present invention could be implemented;

Figure 2 is a flow chart illustrating the steps to
15 derive a physical topology prediction according to an embodiment of the present invention;

Figure 3 is a flow chart illustrating the steps to
derive a set of probable ports to which a specific port is
physically connected according to an embodiment of the
20 present invention;

Figure 4 is a flow chart illustrating the steps to
derive a set of probable ports that a specific port is
physically connected according to an alternative embodiment
of the present invention;

25 Figures 5A, 5B and 5C are block diagrams illustrating a simple network that utilizes piping (5A) of a logical end to end connection at the well known PDH rate VC 12 (5B) over a higher rate VC 4 connection (5C); and

Figure 6 is a flow chart illustrating the steps to
30 prepare logical connection data for analysis according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 is a block diagram illustrating a network in which the present invention could be implemented. The 5 network shown is an optical network although the invention is not restricted to an optical network. As depicted, the optical network of Figure 1 comprises first, second and third spans 30,32,34 that are coupled to first, second and third OPCs 36,38,40. In the case of Figure 1, the first 10 span 30 is a six node BLSR, the second span 32 is a four node mesh network and the third span 34 is a five node BLSR. The three spans 30,32,34 are coupled together via various physical connections. Further within Figure 1 is a Network Manager 42 coupled to each of the OPCs 36,38,40 and a connection database 44 coupled to the Network Manager 42. 15 The normal operation of the network of Figure 1 is well-known in which the OPCs 36,38,40 control the nodes within their respective spans 30,32,34 and the Network Manager 42, controls the operation of the OPCs. As will be appreciated 20 by those in the art, each node includes one or more ports which allow physical nodal connections within and between spans.

It should be recognized that this network is only being 25 illustrated as one sample network in which the present invention could be implemented. The present invention could also be implemented in networks that are more complex with a significant increase in numbers of physical connections and in simpler networks that could include only a single span 30 and no central Network Manager.

Figure 2 is a flow chart illustrating the steps to derive a physical topology prediction according to an

embodiment of the present invention. For the specific implementation described below, the various processing steps of the present invention are performed in the Network Manager 42. It should be recognized that the present 5 invention could be implemented within another processing component within the network and so the present invention should not be limited simply to implementations within a Network Manager.

10 As depicted at step 50, initially the Network Manager 42 receives logical connection information. In one embodiment, to accumulate this logical connection information, each of the nodes within the network provide the logical connection information associated with its 15 particular ports to its corresponding OPC and the OPC forwards this information to the connection database 44 via the Network Manager 42. In this case, when the physical topology prediction procedure of Figure 2 is performed, the Network Manager 42 accesses the logical connection 20 information from the connection database 44. In other embodiments, the Network Manager 42 could request the logical connection information directly from the OPCs or even directly from the nodes. Further, in the case that another processing apparatus is used to perform the 25 procedure of the present invention, it should be understood that various techniques for receiving the logical connection information could be used.

The logical connection information according to one 30 embodiment of the present invention is the Connection Termination Points (CTPs) associated with each port within each node of the network along with logical connection parameters associated with the CTPs. In some embodiments,

2000/00000000

as will be described herein below with reference to Figures 5A-5C and 6, the logical connection information further includes Trail Termination Points (TTPs).

5 For each CTP, the logical connection parameters include
information with respect to which channel within the payload
the CTP is associated based upon the well-known JKLM
indexing scheme. In some embodiments, the logical connection
parameters further include a user label associated with the
10 logical connection of the CTP. In one case, this user label
could be associated with a particular customer that is
utilizing the logical connection such that all CTPs
associated with a particular customer have a common user
label. Further, in some embodiments, the span Internet
15 Protocol (IP) address is used in determining the logical
similarity between ports. The span IP address is a specific
address associated with the OPC for a particular span. The
use of such a span IP address is based on the notion that
there may be more physical connectivity within a span than
20 between spans. It should be recognized that other logical
connection parameters for a CTP could also be used since any
parameters of a CTP that are accessible and could
distinguish between logical connections could potentially be
used as logical connection parameters, as will be described
25 below. Furthermore, it should also be recognized that other
parameters associated with the various ports in a network,
such as the span IP address, could be used in determining
the logical similarity between these ports.

30 Now turning back to Figure 2, the next step within the
procedure, as depicted at step 52, is to prepare the logical
connection information such that the analysis of the
information can be performed more efficiently in subsequent

steps. It is noted that without this step, the present invention could still function properly, but the subsequent analysis of the logical connection information would likely proceed at a slower rate. To prepare the logical connection
5 information, the CTPs are sorted based upon the port within the network that they are associated. In one embodiment, the CTPs for all the logical connection layers, including all PDH rates and concatenated rates such as STS-12c are included in the sorting and the ports are subsequently
10 arranged in order based upon the total number of CTPs associated with the particular ports, starting with the port(s) having the greatest number and ending with the port(s) having the lowest number. This sorting technique will aid in the determination of which ports have the most
15 number of similar CTPs as will be described below. An alternative embodiment to this technique to sort the ports is also possible that does not utilize all of the CTPs from all of the VC layers as will be described below with reference to Figures 5A-5C and 6.

20 Next, as shown in step 54 of Figure 2, the Network Manager 42 proceeds to select the logical connection parameter(s) that are to be used in predicting the physical connections within the network. As discussed above, various
25 different logical connection parameters associated with the CTPs could be used within embodiments of the present invention such as the payload channels that the CTPs utilize and the user labels associated with the CTPs. In some embodiments of the present invention, the step of selecting
30 which logical connection parameters to utilize is done with the use of a Graphical User Interface (GUI) integral to Network Manager 42 in which a user may enter his/her preferences. In other embodiments, the selection of the

logical connection parameters is done automatically by the Network Manager 42 by analysing what parameters are available. In yet further embodiments, the step of selecting logical connection parameters to utilize is not performed and there are default logical connection parameter(s) selected.

Finally, at step 56, the Network Manager 42 analyses the logical connection information as sorted within step 52 using the logical connection parameters as selected within step 54. To derive a physical topology prediction, the Network Manager 42 determines a connection prediction set of ports for a specific port, as depicted at step 57 and described in detail herein below with reference to Figure 3, and repeats this step for all other ports as indicated at step 58. Based upon these connection prediction sets, a physical topology prediction for the network can be generated at step 59 as will be described in more detail below. In an alternative embodiment, physical connection predictions are made based upon the connection prediction sets as they are generated and therefore only ports in which a conclusion with respect to their connectivity has not yet been made have connection prediction sets generated at step 57.

Figure 3 is a flow chart illustrating the steps that the Network Manager 42 performs to derive a set S of most probable ports that a specific port N with M CTPs is physically connected to according to one embodiment of the present invention. The process starts, at step 60, by setting an integer i to one and setting a highest similarity variable x to zero. The highest similarity variable x represents the number of identical CTPs that have been found

between the port N and any ports that are within the set S of most probable ports, two CTPs being identical if each of their respective logical connection parameter(s) are identical.

5

Next, as depicted at step 62, the Network Manager 42 determines a port similarity variable x_i that represents the number of CTPs that are identical between the port N and the port i that is being compared. As mentioned above, two CTPs 10 are deemed identical if all of the selected logical connection parameter(s) are identical. In some embodiments, a level of similarity may be all that is needed to conclude that two CTPs are identical. For instance, if the only difference between the logical connection parameter(s) of 15 two CTPs is their respective user labels, some embodiments of the present invention could still deem the two CTPs to be essentially identical.

20

After determining the port similarity variable x_i for the port i, the Network Manager 42 determines, as depicted at step 64, whether the variable x_i is greater than the variable x, that is whether the similarity between the port N and the port i is greater than the similarity between the port N and the currently found most probable connected 25 port(s). If the port similarity variable x_i is greater than the highest similarity variable x, then the highest similarity variable x is set to the port similarity variable x_i at step 66; the set S containing the most probable port(s) that port N is connected, hereinafter referred to as 30 the connection prediction set S, is reset at step 68; and port i is inserted within the connection prediction set S at step 70.

If the port similarity variable x_i is not greater than the highest similarity variable x at step 64, then it is determined whether the two similarity variables are equal at step 72. If it is determined that the port similarity variable x_i and the highest similarity variable x are equal, then the port i is inserted in the connection prediction set S at step 70.

After either determining that the port similarity variable x_i is less than the highest similarity variable x at step 72 or inserting port i into set S at step 70, the Network Manager 42 proceeds to determine if the number of CTPs of the next port $i+1$ is greater than or equal to the highest similarity variable x . If it is greater than or equal, then there is the potential that the next port $i+1$ could be of greater or equal similarity to the ports within the connection prediction set S . Therefore, as shown at step 76, the procedure of Figure 3 proceeds to set i equal to $i+1$ and then continue the procedure at step 62, determining a new port similarity variable x_i for the new port i .

If, at step 74, it is determined that the number of CTPs for the next port $i+1$ within the sorted list of ports is less than the highest similarity variable x_i , then the procedure of Figure 3 is completed for the particular port N with the connection prediction set S being saved for port N . With the ports sorted by the number of CTPs from largest to smallest, if the next port $i+1$ does not have as many CTPs as the port(s) with the greatest similarity to port N have similar CTPs, then neither the next port $i+1$ nor any further ports that have not been analysed could have an equal or

greater port similarity variable as do the port(s) within the connection prediction set S.

In an alternative embodiment as depicted in Figure 4,
5 the case that the ports are not sorted based upon the number
of CTPs at step 52 is illustrated. In this case, the step
74 is replaced by step 78 in which the Network Manager 42
determines if the port i is the final possible port for
connecting to port N. If it is not, then the procedure
10 continues as before at step 76. In this embodiment, only if
all possible ports for connecting to port N have been
analysed does the procedure terminate. It should be
understood that this alternative procedure could result in
increased processing time to generate a final connection
15 prediction set S for port N.

As described above with reference to Figure 2, after
the connection prediction sets are generated, a physical
topology prediction can be derived at step 59.
20 Alternatively, the connection prediction sets could be
presented to a user for analysis at this point.

The derivation of the physical topology prediction
could be very simple if each of the connection prediction
sets only have two ports within them and there are no
connection prediction sets that contain the same port.
Unfortunately, in a large complex network, this may not
always be the case. In cases that multiple ports are
included within a single connection prediction set, the
25 selection of only one of the ports to predict connectivity
with could occur in a number of different manners. For
instance, a span address for the ports could be used to
decide between two ports with identical port similarity

variables since it is more likely that a connection is local to a span then to be interspan. Another alternative is for the connection prediction set to be presented to a user so that the user can either guess based upon the limited
5 knowledge they have or can send a technician to manually determine the particular physical connection. Yet another alternative is for the connection prediction set to be put on hold until all of the other connection prediction sets have been analysed so as to determine if one or more of the
10 ports within the connection prediction set are predicted to be connected to another port.

TECHNICAL SPECIFICATION

15 The prediction of physical topologies according to the invention have numerous advantages over the manual determining of physical topologies by either entering the information as the network is being connected or manually following cables to check or determine the physical connections after the network is connected. For one,
20 although the prediction is only a logical guess, the accuracy of this procedure after numerous tests using known network information has proven that in most cases, the rate of error (improperly connected ports) is low. On the other hand, using manual techniques has proven in the past to be a largely inaccurate and incomplete technique. Further, the
25 time to complete the predictions is extremely quick compared to the manual techniques while requiring considerably less labour resources.

30 One problem with the procedure according to the invention as described above, is the case where piping is performed. This case will now be described with reference to Figures 5A through 5C. Figure 5A is a block diagram illustrating a simple network comprising first, second and

third nodes 80,82,84. In this case, the first node 80 is piping data to the third node 84, via the second node 82. Figures 5B and 5C illustrate logical depictions of the VC Layer 12 and the VC Layer 4 for this simple network
5 respectively. In this case, as can be seen in Figure 5B, at VC Layer 12, CTPs are only located at the first and third nodes 80,84, thus leaving no logical evidence that the second node 82 is actually physically coupled between the other two nodes 80,84. As depicted in Figure 5C, at VC
10 Layer 4, the Trail Termination Point (TTP) and the CTP are at the same ports within the first and third nodes 80,84 and the second node 82 has a CTP at each of the ports that are connected to the first and third nodes 80,84 respectively.

15 The problem that occurs with piping in the above described procedure of the present invention is due to the fact that within VC Layer 12, it appears, based upon logical connections, that nodes 80 and 84 are connected together directly. Therefore, errors could arise in which the port
20 at the first node 80 is determined to be connected to the port at the third node 84. To overcome this problem, a slightly modified process of preparing the logical connection information for analysis as shown in step 52 of Figure 2 is utilized as shown in Figure 6. As depicted at
25 step 90, initially all of the CTPs and TTPs for all ports within the topology to be considered are captured. Next, it is determined whether piping is occurring at step 92. This can be done by determining if there are any situations in which a CTP is at the same port as a TTP. IF it is
30 determined that piping is occurring, then the procedure can filter out all higher layer CTPs as depicted at step 94, thus removing the circumstances illustrated for VC Layer 12 of Figure 5B. Finally, after either step 92 or 94, the

procedure can sort the ports based upon the number of remaining CTPs at step 96 in a similar fashion as described previously with respect to step 52 of Figure 2.

5 It is noted that the procedure as described for the present invention could be utilized to generate a physical topology for a network with no additional information or alternatively could be aided by other information to make the analysis simpler. For instance, the procedure of the
10 present invention could be used simply to check physical connections and therefore either the operator or the Network Manager 42 itself could use the previous information to aid in selecting between a plurality of ports within a single connection prediction set.

15 Further, an incomplete set of physical connections for a network could be used to reduce the number of ports for which connections are not known and therefore reduce the number of connection prediction sets that must be generated.

20 Still further, an auto-discovery technique could be utilized to provide information with respect to some connections within the network. For instance, one auto-discovery technique that could be utilized with the present
25 invention is disclosed within a U.S. patent application "XXXXXXXXXX" entitled "XXXXXXXXXXXX" by XXXXXXXXXX, assigned to the assignee of the present invention and herein incorporated by reference.

30 Persons skilled in the art will appreciate that there are alternative implementations and modifications of the present invention, and that the above-described implementation is only an illustration of specific

embodiments of the invention. Therefore, the scope of the invention should only be limited by the claims appended hereto.

TRANSMISSIONS/2660